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ECL 180

ASCENDENT ELECTRIC COMPANY

A Case Study

This case was prepared by Professor David P. Rutenberg of Carnegie-Mellon University as a basis for class discussion rather than as an illustration of either effective or ineffective handling of an evolving situation. This case was made possible by the enthusiastic cooperation of a business firm which then chose to remain anonymous. Therefore, certain names, places, and figures have been disguised.

ASCENDENT ELECTRIC COMPANY

Industrial Marketing of Large Technical Products

Introduction to Ascendent Electric

The Ascendent Electric Company had been growing at a rate of over 10% a year so that its 1968 sales exceeded $3 billion. In its early days, the company established its reputation by building generators and transformers for electric utility companies. This Electric Utility Group was now just one of six product groups, the others being Aerospace-Defense-Marine, Specialty Products, Construction, Consumer Products, and Industrial Products. A cluster of product divisional managers reported to each group vice president. The rationale behind this organization was that interacting divisions should be grouped together under a group vice president. The impact of product divisionalization on an industrial salesman (who sourced products from many divisions) was to force him to rely on his informal contacts and persuasive ability. For example, in this case, a salesman based in the Industrial Products group developed an order most of which was to be manufactured by a division of the Electric Utility Group. Ascendent was a long-established company which had not undergone periods of explosive growth, so informal communication and assessment of market opportunities was quite accepted and quite reliable. In a company with annual sales of $3 billion a $2 million order to the Silicon Stainless Steel Company may appear small, but the order does provide a glimpse of the intimate collaboration between various product divisions and between the functions of marketing, design engineering and manufacturing.

Introduction to the Silicon Stainless Steel Company

With annual sales of just over $2 billion for most of the years since 1956, Silicon Stainless was the fourth largest producer of steel in the U.S.A. It had steelmaking plants at Cleveland, Ohio; Detroit, Michigan; Newark, New Jersey; Pittsburgh, Pennsylvania; New Orleans, Louisiana; St. Louis, Missouri; Fort Worth, Texas; and Omaha, Nebraska. Most products of Silicon Stainless were specialty steels, sold fabricated. Although foreign competition had caused concern it had not dug as far into the sales of Silicon Stainless as it had into those of some other American steel companies, because the products of Silicon Stainless were non-standard, custom-tailored and because most of the company plants were located inland.

In 1964 the President of Silicon Stainless, Logan G. Robinson, announced a massive, coordinated expansion program to be completed by 1970 which would cost approximately $900,000,000; hence, the name: Project 900. Project 900 was the embodiment of Mr. Robinson's belief that "the future will be served by those companies which anticipate and take steps to prepare themselves for it". The Detroit plant was included in the expansion plans of Project 900. From the automobile companies, principally General Motors, Detroit purchased clean scrap of known metallurgical specifications, melted this scrap and added alloying metals. It manufactured both stainless steel and high silicon steel; our attention in this case will focus on high silicon steel which was marketed for transformer cores.

As steel company after steel company in the United States installed Basic Oxygen Furnaces (BOF) the price of scrap steel dropped because the BOF can be loaded with no more than 30% cold metal without congealing. The steel companies could not use as much scrap; they therefore purchased less. Scrap prices dropped. Silicon Stainless noted that the industrial price for electric power had not increased appreciably over the years, and that there had been improvements in the design of the electrical arc furnaces. These facts led Silicon Stainless to specify electric arc furnaces for their new Detroit melt shop.

From the vantage point of Project 900 of Silicon Stainless, the topic of this case may appear small as it covers just the Detroit plant. Among the many projects at the Detroit plant, this case focuses exclusively on the melt shop. The total cost of the melt shop was $40,000,000, and of this only 5% represented the cost of the electrical equipment supplied by Ascendent Electric.

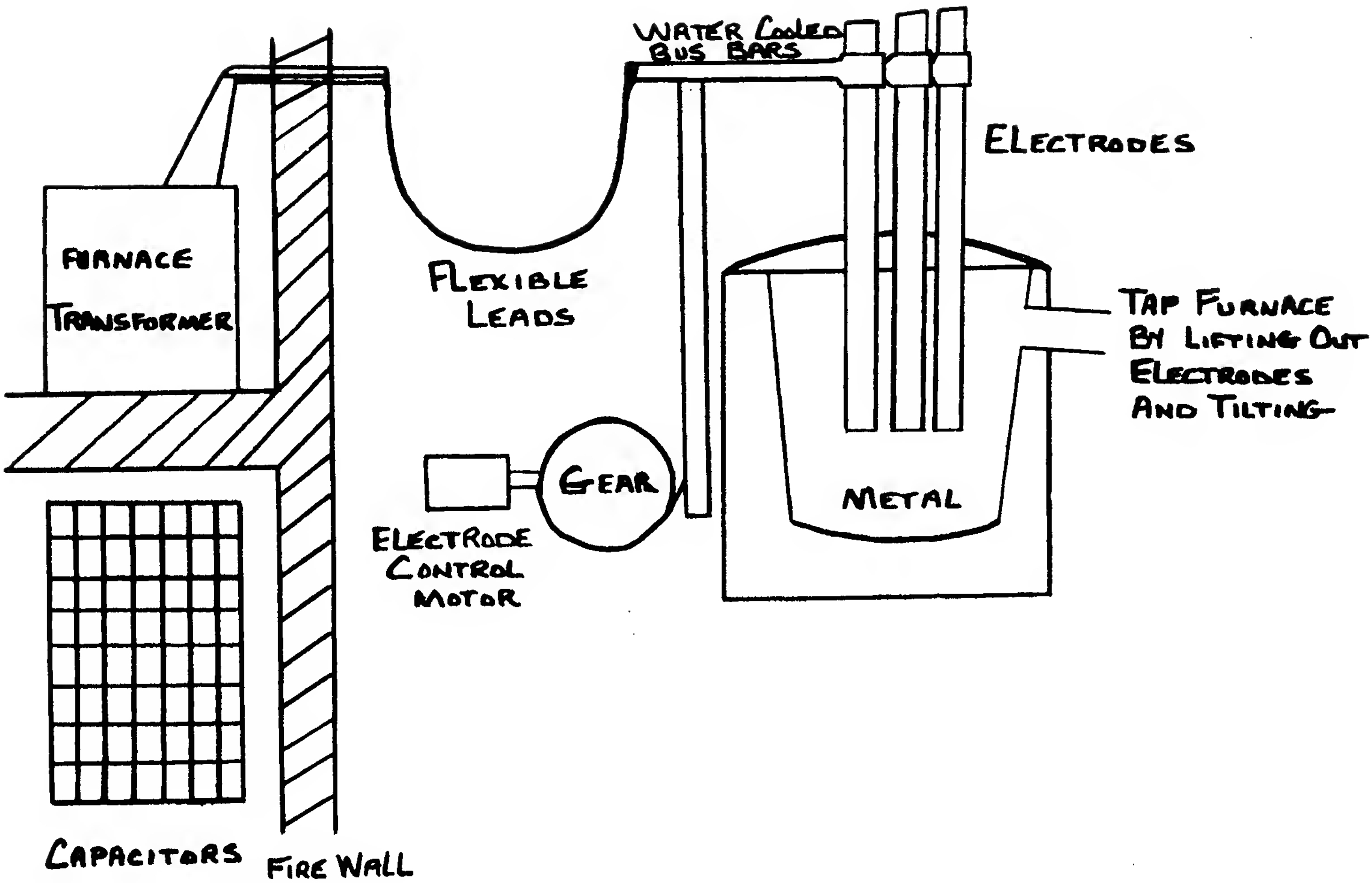


Figure 1: SKETCH OF AN ELECTRIC ARC FURNACE

PART 1

Sizing the Furnace (75 months before start up)

It is a feature of industrial marketing that the customers of Silicon Stainless expect steels metallurgically tailored to their special needs and fabricated to their requirements. Just as Silicon Stainless has to perform this engineering work before its customers make a commitment to buy, so similarly the Detroit plant of Silicon Stainless relies upon the engineering talents of companies which sell to it. Electrical power problems were referred to industrial salesmen from the various electrical manufacturing companies such as Ascendent. The Ascendent field sales engineer had to provide the Silicon Stainless Detroit account with advice which was relevant and valuable to them. In fact, an occupational hazard of a good field sales engineer has been that his customer would so appreciate the value of his advice that he would hire the engineer.

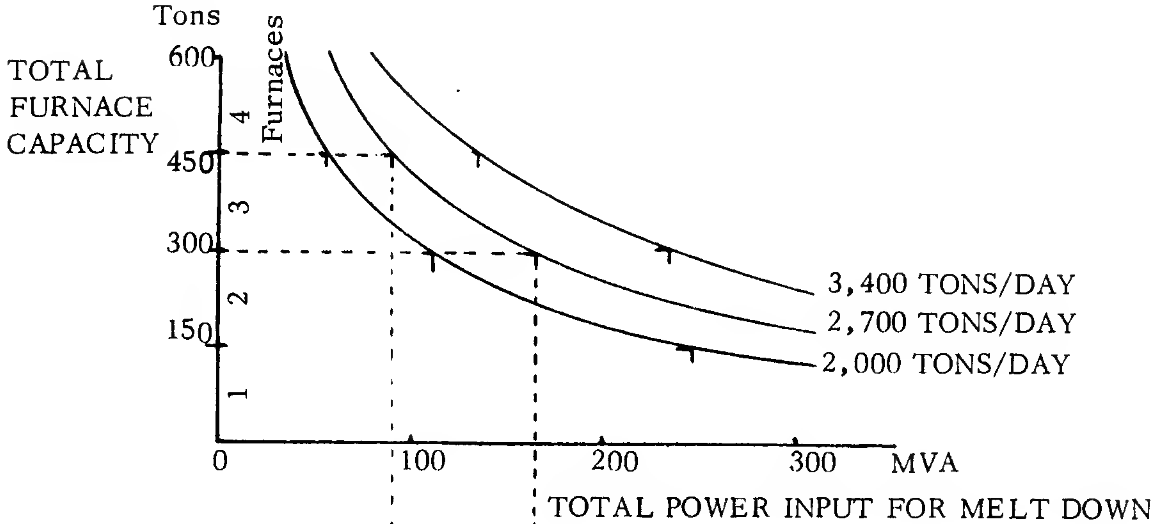
Nick Borris was the Ascendent field sales engineer who saw the Detroit melt shop from inception to completion. Since 1957 he had been responsible for four steel mill accounts of which the Silicon Stainless Detroit mill was one. Over the years he had become closely associated with the engineers of Silicon Stainless Detroit, and his advice, judgment, and confidence were respected. Although Project 900 was not publicly unveiled until 1964, preliminary planning work had been in progress for over a year. On January 10, 1963, Nick Borris was invited to the Detroit plant to discuss innovations in electric arc furnace control. Ed Borrach, the widely recognized Ascendent expert in arc furnace control, accompanied him. Before the meeting the Detroit engineers were thinking in terms of two arc furnaces, each 28' in diameter, each with a power input of 35 MVA. At this meeting one of the first considerations faced by Nick Borris was to ascertain what the duty cycle Silicon Stainless anticipated for this melt shop. A typical duty cycle could be:

furnace adjustments	10 minutes
2 scrap charges	10 minutes
melt-down	X minutes
refine time	35 minutes
tap time	15 minutes
TOTAL TIME	70 + X minutes

The scrap metal is compacted before being loaded into the furnace, but even after compaction a given volume of scrap still consists of only fifty percent metal (the other fifty percent of the volume consists of air void). Instead of building high furnace walls, in each duty cycle it is cheaper to shut down the furnace for five minutes to load the second half of the scrap charge after the first load has melted. Assuming the electrical power input is adequate for refining, then the refining time, the tap time and the period for furnace adjustment and for charging were not subject to change. For 70 minutes of every duty cycle the power system idles. However, melt down time varies inversely with the power input. The shorter the duty cycle, the smaller (less costly) the furnace need be to satisfy a daily demand for steel. The problem, therefore, was reduced to balancing the investment cost of a power system against the investment cost of furnace capacity. Although there were economies of scale in furnace and transformer costs it was felt by Silicon Steel that no furnace should exceed 150 tons capacity for to do so would push too far beyond the current art of furnace building.

The demand for silicon steel originated with companies such as Progress Electric, Ascendent Electric, and others who build transformers. Thus the market forecasts for Silicon Steel were as good as the market forecasts for electric power. Areas of uncertainty originated from these uncertain forecasts for total electric power, from the possibility of improvements of transformer design that would utilize less steel, from the possibility that American transformer builders would purchase foreign steel, from the possibility that American public utility companies would buy foreign built transformers, and finally from the market share that the Silicon Steel Company could expect. In their meeting with the engineers of Silicon Stainless of Detroit, Nick Borris and Ed Borrach were convinced that two 35 MVA furnaces would be inadequate for economical operation. Transformers designed to run at 35 MVA could be operated at 45 MVA but the power losses would be substantial; thus for a reasonable cost of capital the customer would be advised to run his transformer at design power.

Figure 2: TRADE OFF BETWEEN TOTAL FURNACE CAPACITY AND TOTAL POWER INPUT



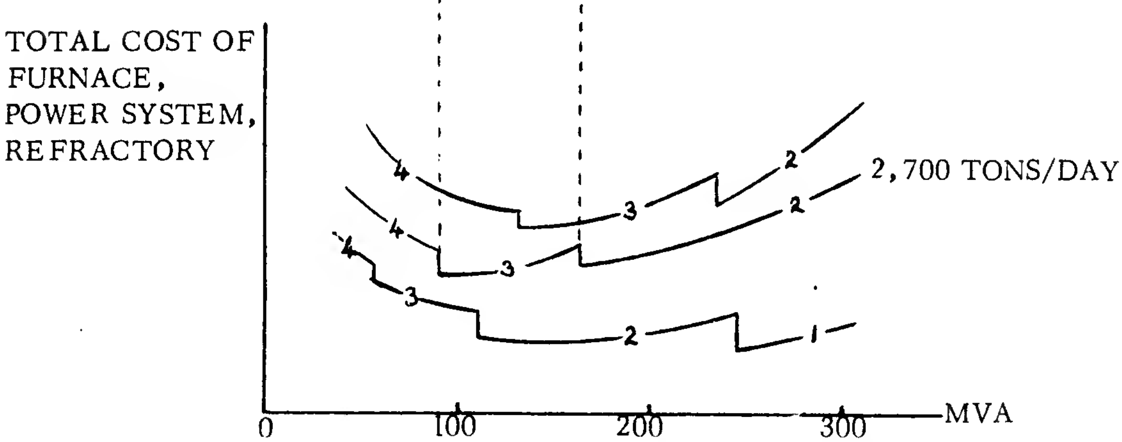


Figure 3: TOTAL COST OF FURNACE, POWER SYSTEM, REFRACTORY

If the demand for steel were known with certainty it would have been possible to calculate the locus of points between total furnace capacity and total power input for melt down, any one point of which would satisfy the known demand. For reasons of reliability it had been decided by the Silicon Stainless engineers that each furnace would have its own transformers (as opposed to linking the furnaces by a massive bus bar fed by one central transformer). The economies of scale in the cost of the furnace and its attendant transformer (subject to the maximum furnace size of 150 tons) resulted in the Figure 3 estimates of the total cost of furnaces plus power systems for each point on the above family of curves. These questions were raised at the Detroit meeting on January 10, 1963. Subsequent analysis became quite complex for the Silicon Stainless Steel Company, Detroit plant, faced an uncertain but rising demand and had to be concerned with means of providing an expandable output. A sudden receipt of orders could be met by shortening the melt down period by running the transformers at a higher power than their design rate. However, a long run increase in demand would better be met by building additional furnaces than by installing higher powered transformers. It was for this reason that Nick Borris felt obliged to rebut the suggestion of one Silicon Steel engineer that each furnace be equipped with a 67 MVA transformer.

A further complication that the Silicon Steel engineers faced was that 15 different grades of silicon steel had to be manufactured. Some of these grades were so difficult to alloy that the Silicon Stainless Steel Company had to try two or three melts before achieving specification products. The off-specification steel fell into lower value grades. Because of this manufacturing difficulty, Silicon Stainless charged a higher price for these grades and received only small orders. The Silicon Stainless engineers had found that when a 150 ton furnace was used for a small order of, say, 50 tons, radiation from the arc shortened the life of the refractory furnace lining for it was not shielded by molten metal. Therefore, they questioned the wisdom of building identically sized furnaces, and suggested that at least one be appreciably smaller than the others.

Clearly some decisions had to be made about the furnace size and power. What assumptions were the Silicon Stainless engineers making, and what sort of rational analysis could Borris and Borrach of Ascendent Electric outline to these engineers that would enable them to find a solution that was optimal in total costs, flexibility, expandability, and ability to handle small orders? The final decision was that the Detroit plant site would be adequate for approximately ten furnaces (the building is built on approximately 35 feet of fill and so over 7,000,000 cubic yards of fill had to be placed). The melt shop would be sized for five furnaces, of which only three would be installed. These three furnaces would be identical, 150 ton capacity, 56 MVA design power input. An old 60 ton furnace from an obsolete plant (about to be demolished) would be moved to Detroit at some time after start up as a fourth furnace.

PART 2

Investment in Proposals (74 - 22 months before start up)

The Industrial Systems Division of Ascendent Electric contained a special department of Metals Industry Systems. One of the groups within the department was concerned with metal making and consisted of 10 engineers headed by Bill Muson. The metal making group was responsible for electrical drive systems involved in blast furnace control, basic oxygen furnaces, continuous casting, vapor deposition, and electric arc furnaces. The Industrial Systems Division of Ascendent Electric worked as consultants within Ascendent Electric. Each group focused on an industry, on a function, or on a process and monitored developments around the entire world. In this way they were able to provide customers of Ascendent Electric with sophisticated analysis and informed opinion.

Within Ascendent Electric there were many sources of expertise, such as the Bill Muson group. One of the problems facing Nick Borris was that of knowing about the existence of these groups within his own company so as to utilize their expertise on the problems of the Detroit melt shop of Silicon Stainless Steel.

As has been mentioned the initial contact for the Detroit melt shop came in January, 1963; the first melt was not made until spring 1969. During this six year interval there were a number of engineering developments in the process control of arc furnaces. At any instant Nick Borris could source information from the various technical groups within Ascendent Electric (such as the group managed by Bill Muson) either informally through telephone calls and meetings, or formally by asking for a proposal. It was the policy of the Industrial Systems Division that a project pass through five different proposals:

(1) Appropriation
(2) Preliminary
(3) Close Estimating
(4) Firm
(5) Final

Requests for appropriation proposals originated both from steel companies and from mill builders. Rather rough estimates were adequate. In fact one of the key problems lay in keeping track of all the estimates given for the same steel mill expansion. The same job, camouflaged by each mill builder, would come to the metal making group for proposals and quotations time after time. For this reason the metals making group developed the cynical opinion that preliminary requests from the mill builder were most unlikely to result in an order.

The problem faced by Nick Borris at each of the five stages of proposals and quotations lay in convincing groups such as that of Bill Muson that it was worthwhile for him to spend hundreds of manhours on this order. Obviously if Ascendent Electric was very unlikely to receive the ultimate order Nick Borris could not expect the Industrial Systems Division to spend tens of thousands of dollars on a proposal. On the other hand such expenditures might well be justified if Ascendent's chances were near 50% and a better proposal would increase the percentage probability that Ascendent would receive the order.

To better understand the internal corporate problem of communication and motivation faced by Nick Borris it may be best to analyze the optimal allocation of time by a typical engineering group such as that of Bill Muson.

At the beginning of each month Muson has 200 mandays to allocate to projects. Assuming steady state, in each and every month there are the same number of appropriation requests, preliminary requests, close estimating requests, firm requests, and final requests. Time spent on each project increases the probability that it will be requested in the next quotation stage, and that it will result in an order. That is to say, assume that only appropriation requests are determined exogeneously but that the number of requests that survive to preliminary or later stages is a function of the amount of work that has been done by the Muson group. How then should Bill Muson allocate his 200 mandays? Repeat the analysis making different assumptions as to the information Muson would require of a sales engineer such as Nick Borris. For each assumption (in that the projects of Nick Borris constitute only a small portion of the total projects of the month) determine in what way Nick Borris could manipulate the system to get a maximum amount of work done on his projects. How would the analysis change if Muson expected a non-steady state workload (1) to have more engineers assigned to him, or to face a long-run downtime in the number of requests or to have on line computer time, (2) Muson expected to be losing some of his men, or anticipated a boom in steel making, or if he decided to use some of his men to develop a package of engineering design computer programs?

PART 2 - CONTINUED

In practice the sales engineers have tended to say that the probability equals one divided by the number of companies competing. The effect of this is to decrease high probabilities and increase low ones so that all probabilities fall within the 30-70% range. Quite apart from the problem of subjectively estimating probabilities, is the fact that the sales engineer wants engineering design done now. Low probabilities have been increased so as to get more work done on the project. High probabilities have been decreased (especially on early types of quotations) so that the engineering design work will be done when needed, rather than being delayed for several months or years.

The field sales engineers have been likened to football quarterbacks who call plays. They are in constant telephone touch with the diverse design engineering groups, and as individuals they become known so that the information they forward is evaluated in terms of their past history. When a new sales engineer enters the system, the design engineering groups check with his manager in the field to determine the extent to which his assertions should be valued. One of the challenges facing the field sales manager is that of helping the young salesman perceive accurately his chances of receiving each order. One of the challenges facing the manager of an engineering design group is that of compensating accurately for the cycles of optimism and pessimism through which a young sales engineer passes.

The proposal for Silicon Stainless Steel consisted of an analysis of a customer's requirements, followed by a lengthy bill of materials which Ascendent Electric proposed as suitable for the job. Copies of the proposal were sent to all the divisions whose products were included, and it was the responsibility of the division marketing personnel to quote their prices. Some items were standard or stock and could be priced on the basis of competition. For example, standard circuit breakers were made by many companies including Ascendent and the division marketing men always monitored circuit breaker prices in each major city in the United States. On the other hand non-standard circuit breakers, non-standard electric arc transformers, and any other job shop items were unique; thus a separate price had to be derived for each. The component costs were then summed to the total cost, which in turn was sent to Nick Borris and his field district sales manager. Based on their estimate of the competition, they had to accept or reject this price before revealing it to Silicon Stainless Steel. Had the price appeared too high, Nick

Borris was prepared to scrutinize each quotation from each division, select those that seemed high, then telephone the offending divisions in an attempt to get the prices shaved. The preliminary prices were not unreasonably high, so Nick Borris chose not to pressure the divisions, preferring to wait until the design schemes have been resolved. For example, in October 1964, Borris submitted the Ascendent preliminary proposal to Silicon Stainless Steel. Three schemes were presented:

	Transformers	Switchgear	Distribution Apparatus
Scheme 1	$1,462,000	$ 470,000	$ 165,568
Scheme 2	$1,185,000	$ 407,677	$ 165,568
Scheme 3	$1,358,000	$ 418,257	$ 165,568

Nick Borris was of the opinion that the above prices were somewhat high, but until the customer made the decision as to the scheme he would use, Borris felt that Ascendent should not reveal its best prices.

Scheme 1, the most expensive, proposed a load tap changing transformer. Load tap changing transformers have been used in electrical utility companies for many years. If output voltage has to be changed, and load tap changing is not possible, then the transformer must be shut down for an instant while the tap is changed. The disadvantage of load tap changing is that arcing contaminates the transformer oil. In public utility companies regular maintenance was done and this proved to be no problem. In steel companies there had been no tradition of adequate preventative maintenance. Scheme 1 of the Ascendent Proposal to Silicon Stainless noted this maintenance problem, and also noted the reduced melt down time that could be achived by a load tap changing transformer and hence the additional steel that could be produced for a given investment in equipment. Furthermore, the proposal explained that if load tap changing equipment were used, a process control computer could be installed to regulate the total power consumption and avoid peaks of power demand, which were charged an appreciably higher rate than a stable power demand. The economic implications of load tap changing with a process control computer were such that not only did Silicon Stainless choose Scheme 1, but they also reopened for engineering study their New Orleans plant, cancelled their order for no load tap changing equipment from a competitor of Ascendent, and awarded the project to Ascendent.

PART 3

Power Company Meetings (53 months before start up)

When Silicon Stainless had expanded their Pittsburgh blast furnace the Frazer Engineers had done extremely good work for them in supervising construction. In August, 1964, Frazer was awarded the contract to engineer all phases of the Detroit expansion. Since the new melt shop was only one job in an overall expansion of the Detroit plant and they planned to be in Detroit through 1971, Frazer immediately moved 20 engineers to Detroit and expected to add another 15.

In the early fall of 1964 Nick Borris met with the district sales manager and field sales engineer of Ascendent Electric whose account was the Detroit Edison Company, power company for Silicon Stainless Steel, Detroit. The purpose of the meeting was to tell them that Detroit Edison would have to install an additional sub-station (transformers and breakers) and that this additional demand from the Silicon Stainless melt shop would tend to move forward the expansion plan of Detroit Edison. The meeting was also to brief Borris on expansion plans of Detroit Edison, to prepare him for a series of joint meetings between Silicon Stainless, Frazer Engineers, Detroit Edison, and himself, representing Ascendent Electric to assure that the power system would be adequate. The meetings were held, and from information received about the impedance of the proposed transformers Detroit Edison made computer studies of their system stability. One point on which they were vehement was that they did not want harmonic transients originating within the furnace transformers to affect their system. The billing formula was also negotiated between Detroit Edison and Silicon Stainless. The monthly power consumption was expected to be about 90,000,000 kilowatts, which would cost approximately $500,000 per month.

The billing formula was 0.5 total power + 0.5 maximum 15 minute integral within the month, subject to the constraint that the highest peak of power should be less than 1.4 times this maximum 15 minute integral.

Predictions of demand for electrical power were presented, discussed, and re-evaluated. For example, on November 23, 1964, the chief engineer of the Pittsburgh headquarters of Silicon Stainless Steel joined the four party meetings, and reopened for discussion the question of transformer sizes. He recommended 67 MVA in place of the 45 MVA on which all proposals had previously been made. Detroit Edison promised to study how this additional transformer capacity would affect the system and report back within two weeks. The outcome of that meeting was Silicon Stainless's decision to plan on the basis of 56 MVA equipment. Nick Borris was at ease in discussing electric utility power systems, rolling mill drives, electrical arc furnaces and other heavy electrical equipment. He had 20 years of experience with this equipment, knew who to telephone in divisional marketing and divisional engineering and even in divisional manufacturing, to get information and to prod for more speedy delivery. But no salesman can know everything, and Nick Borris did not have this depth of experience with process control computers. Ed Borrach, the Ascendent expert on arc furnace design, had recommended that load tap changing transformers be used in conjunction with a process control computer, and his analysis had not only won the inside track on the Detroit melt shop, but had retrieved for Ascendent the firm order for the melt shop in New Orleans. Given the Detroit Edison billing formula, and the fact that there were three furnaces over which to allocate the electrical power, it appeared that a properly formulated computer program with adequate forecasts of monthly steel demand would result in a substantially reduced electrical bill each month.

Nick Borris scheduled a December 9, 1964 meeting with Silicon Stainless Detroit engineers to discuss the process control computer for their arc furnaces. He had had very little contact with the computer division of Ascendent Electric. As has been noted, the suggestion to use process control computer with load tap changing had come from Ed Borrach, not from Nick Borris. Borris wanted to bring to the meeting an Ascendent computer expert who would give a first impression of talent. Simultaneously, however, he wanted someone who was cautious enough not to overcommit and overpromise on computer performance before realizing the full implications of the process control problem facing the arc furnaces. Borris's problem in contacting the computer division of his company was rather like the problem faced by any manager who brings in an outside consultant to advise him on problems he does not quite understand, yet whose recommendations he must judge and evaluate.

PART 4

Defense Against Accusations (52 months before start up)

Each furnace has three electrodes. Each electrode is raisable and lowerable so that the arc can be moved down as the load of scrap is melted. The electrode, a carbon rod 15 feet long and 24 inches in diameter had to be positioned accurately and quickly (for an A.C. arc is unstable and tends to extinguish itself). Each electrode is controlled by an electrode control which feeds an electrode control motor, which in turn feeds into a gearing system. Until 1964 most furnace manufacturers used worm gear drives for their electrode control motors. Thus when the electrode was not being moved, it was supported by the friction of the worm gear. A disadvantage was that worm gear drives were sluggish. To achieve faster responses, U.S. furnace manufacturers started to change from worm to helical gear drives. Due to an unfortunate failure in communication, the consequences of this design change were not realized immediately.

For example, arc furnaces with Ascendent controls and motors were installed at Lupin Steel and Romping Steel. The rated capacity of the motors was quite adequate had worm gear been used, but were quite inadequate for helical gears, in that the motors were in service continuously either lifting or in a locked position. The windings roasted out and the motors smoked. The design error was realized and larger motors were substituted. It was a slight embarrassment to Ascendent Electric, but the fault lay with the furnace builder who had specified the motors.

It so happened that instead of regular mill motors, permanent magnet motors had been used to reduce rotational inertia, and to simplify maintenance. Permanent magnet motors were something of an innovation in the steel industry, and as talk of the burned out motors spread throughout the steel industry, the fact of inadequate motor rating became confused with the fact that the motors were permanent magnet and that both installations had an Ascendent Quadrostat control system.

On one of his frequent visits to Detroit, Nick Borris was told of these rumors by a Silicon Stainless engineer whom he trusted. This engineer had attended a meeting between Silicon Stainless and the All-American Bridge Company. All-American had made a definite point of informing Silicon Stainless that the Ascendent Quadrostat controls were performing badly at Lupin Steel and Romping Steel, so badly in fact, that permanent magnet motors had burned out. It was December 30, 1964. Nick Borris immediately phoned Ed Borrach, the Ascendent arc furnace specialist, asked him to check on the Lupin and Romping installations, and report back on his findings. Nick Borris met the new year of 1965 with the results of Ed Borrach's cursory check, and the need to calm his most important customer. How?

PART 5

Maintaining Customer Interest (50 - 30 months before start up)

After the busy winter of 1964-65, two years were to pass before the Silicon Stainless Board of Directors gave their final approval for the Detroit melt shop. For two years the Detroit engineers were to have their aspirations repeatedly frustrated as their melt shop project was delayed, and delayed. In March 1965, the entire Project 900 was over two months behind schedule. In April it was announced that the project was three months behind schedule due to Frazer Engineers' inability to hire electrical engineers capable of handling the complex interactions of this project. In May, the Pittsburgh headquarters of Silicon Stainless announced that the Detroit melt shop would be delayed indefinitely. The immediate reason for the delay was a management reorganization in the headquarters of Silicon Stainless. The more fundamental reason for the delay was that the 1965 leadership election within the United Steel Workers Union caused a long delay in labor negotiations, the new president felt that he had to prove himself and it was anticipated that wage costs would be appreciably higher. Silicon Stainless had borrowed $300 million in short term loans for their Project 900, and had planned to fund the remaining $600 million from internally generated retained earnings. Higher wages meant lower forecasts of retained earnings, which necessitated postponing several items in Project 900, including the Detroit melt shop.

While the Detroit plant accounted for only 22% of the Silicon Stainless tonnage, the high quality of its products and the efficiency of its operation enabled it to generate 37% of the corporate income. Furthermore, the Detroit plant had been profitable for many years, and was well managed. It had a tradition of independence from the Pittsburgh headquarters. The Detroit chief engineer decided to get the project moving by using his contingency fund to clear the site and move earth for the foundations. But the amount of earth to be moved had been underestimated, the contingency fund was exhausted, and as a result even site preparation was delayed. Ultimately, 7 million cubic yards of fill were moved. Effective July 1, 1965, the chief engineer was relieved of his job and was promoted to Area Superintendent of the proposed melt shop and rolling mill.

In order to better understand the quiet years of 1965-66, it may be helpful to recall the four parties: (1) Silicon Stainless Pittsburgh Headquarters, (2) Silicon Stainless Detroit, (3) Nick Borris of Ascendent Electric, (4) Divisions of Ascendent Electric. Nick Borris was not on commission, but his year-end bonus depended on his annual sales; perhaps a more important motivation than his bonus was that Borris had come to identify with the engineers of Silicon Stainless Detroit, and wanted his account to grow in importance and stature. He had no direct means to influence decisions at Silicon Stainless Pittsburgh Headquarters and could only provide information to the Silicon Stainless Detroit engineers, and encourage them to fight hard for their expansion.

However, Borris was an employe of Ascendent Electric. His engineering studies were to be done by the numerous product divisions of Ascendent Electric. Insofar as they had faith that an order would emerge from their work, these divisions would do good engineering studies. Insofar as the product divisions thought that hopes of a Detroit melt shop were futile they would not use their best talent on it. In the extreme, if his district manager felt that Nick Borris had no prospects for sales at Detroit, another account would have to be added to Nick Borris's load.

During the summer of 1965 Nick Borris spent a great deal of time gathering information and conferring with Frazer Engineers and Silicon Stainless Detroit engineers so that the latter could write specifications for a number of small expansion projects. By assisting in writing specifications, a sales engineer can contribute considerable of his company's technical competence to the solution of the customer's problems. Competitive products may frequently differ somewhat in performance. Therefore, when reviewing the final specifications it becomes relatively easy for competitors to identify the manufacturer who gave specification writing assistance. This may or may not influence their bidding technique. To Borris, however, the key motivation behind his help on the specifications was to keep an expansion minded attitude among the engineers of Silicon Stainless Detroit.

If the expansion program were to be built, a thorough study of the Detroit switchgear and substation equipment would be necessary. The existing switchgear operated with the existing demand, but was obsolete. Silicon Stainless could have called in an outside consultant to make the study, but undoubtedly his costs would have been greater than that of Ascendent, who viewed the study as an opportunity to maintain morale at Detroit, and as a required marketing expenditure for switchgear. From the information Borris received at a meeting before the order was given, he estimated that Detroit would be in the market for appoximately $250,000 worth of switchgear for the next two years. On Friday, December 4, 1965, Ascendent received an order for $1,350 to make a bolted short circuit study of the Silicon Stainless Detroit distribution system. During the spring of 1966 there was very little action. It became apparent that Ascendent had competition from Progress Electric and from Kentucky Transformer on the arc furnace transformers. Such competition was to be expected, though Borris was quite disturbed when the Silicon Stainless Pittsburgh purchasing department, the formal purchasing department for all divisions, allocated an order for 2,000 KW rectifiers (totalling $125,000) to Progress Electric without competition, even though Silicon Stainless Detroit and the Frazer Engineers had requested that Ascendent be asked to bid.

Each of the three electrodes of an arc furnace was positioned by a separate DC motor. The source of DC power was an AC motor driving a DC generator. The cost of <u>each</u> motor generator set (9 were required) was about $13,000. In late 1965 the Industrial Systems Division of Ascendent Electric had developed a robust static power converter system, suitable for any application where there was a requirement for regenerative power, controlled stopping, and reversing. It was available in sizes from 5 horsepower to 200 HP. The cost would be about $15,000 for each static power converter system compared with $13,000 for each motor generator set, control would be more responsive, and the maintenance problems of motor generator sets would be ended. So in December Borris arranged that the Ascendent mobile display truck of control equipment would visit Detroit. Approximately 20 people from Silicon Stainless and Frazer Engineers came to see the display. Nick Borris had been told by the Silicon Stainless Detroit engineers that the Progress Electric quotation on their type of static power converter would be $14,000 per unit.

Price, however, was not really the problem. To many steel men it seemed inconceivable that a quiet gray box could perform the work of a motor generator set more efficiently and with greater sensitivity of control. They had to be convinced, they doubted that it was reliable. Borris faced the problem of convincing them, and of establishing a price. Detroit still had no authorization to spend money from the Board of Silicon Stainless.

PART 6

Scheduling the Transformer Orders (26 months before start up)

On September 6, 1966, Nick Borris received a telephone call from Frazer Engineers, representing Stainless Silicon, requesting the Ascendent selling price for the three 56,000 KVA furnace transformers and the three 56,000 KVA load tap changing regulating transformers. They wanted to get the order placed because of the long delivery time on heavy transformers. In response to the price quotation of $1,105,000 for the three transformers of each type, Ascendent received a "letter of intent" from Stainless Silicon via Frazer Engineers. This letter arrived in December 1966.

It was not until February 24, 1967 that the Stainless Silicon Board of Directors gave a $30 million approval for the Detroit melt shop. It was not until March 1967 that Silicon Stainless awarded the furnace building contract to the firm Swindell-Dressler, and even then the question of who would supply the electrode controls was undecided.

One of the main reasons that Silicon Stainless Detroit took the precarious position of issuing a "letter of intent" on the transformers was that the transformer division of Ascendent was quoting a delivery time of 20 weeks for engineering and drawing, followed by 50 weeks of construction. Issuing a letter of intent assured delivery of the transformers in 70 weeks. The costs of breaking a letter of intent would have been small given that Ascendent was supplying Silicon Stainless with equipment for all of their plants, and could have negotiated away the penalty payments. In many applications, delivery date negotiations were as important as a price negotiation. Although Nick Borris did not have control of the lead times, he had to understand the estimating procedure of the transformer division.

The production planning committee of the transformer division consisted of the marketing manager, engineering manager, and the manufacturing superintendent. This committee was aided by the manager of production material control, and the operations researcher with the title of Supervisor of Materials Control and Scheduling. Every two months the committee issued a concise one-page list of the 71 different transformer types manufactured in the division. Beside each type was a prediction of the number of weeks required to get approved drawings, and the number of weeks required for manufacturing. The transformer plant had been operating on three shifts per day, seven days per week; hence the long lead times. The field sales engineers generally

wanted the lead times reduced, but were vehement that the promised delivery date be met. One of the regulating transformers for Silicon Stainless Detroit was shipped 13 days late. This slippage was unusually high; the majority of the jobs were shipped on time and very few were more than 5 days late.

To an arc furnace engineer such as Ed Borrach the transformers for Silicon Stainless Detroit were different; each had unique features. But, to a manufacturing engineer, the transformers all went through the same manufacturing steps. For example, they all required that the coils be wound, and cores be stacked. Unique performance characteristics for a particular transformer were achieved by winding different coils, with different taps, or by stacking different sized cores; nevertheless, the sequence of manufacturing steps were standard. For this reason it was possible to keep track of the transformers using critical path diagrams.

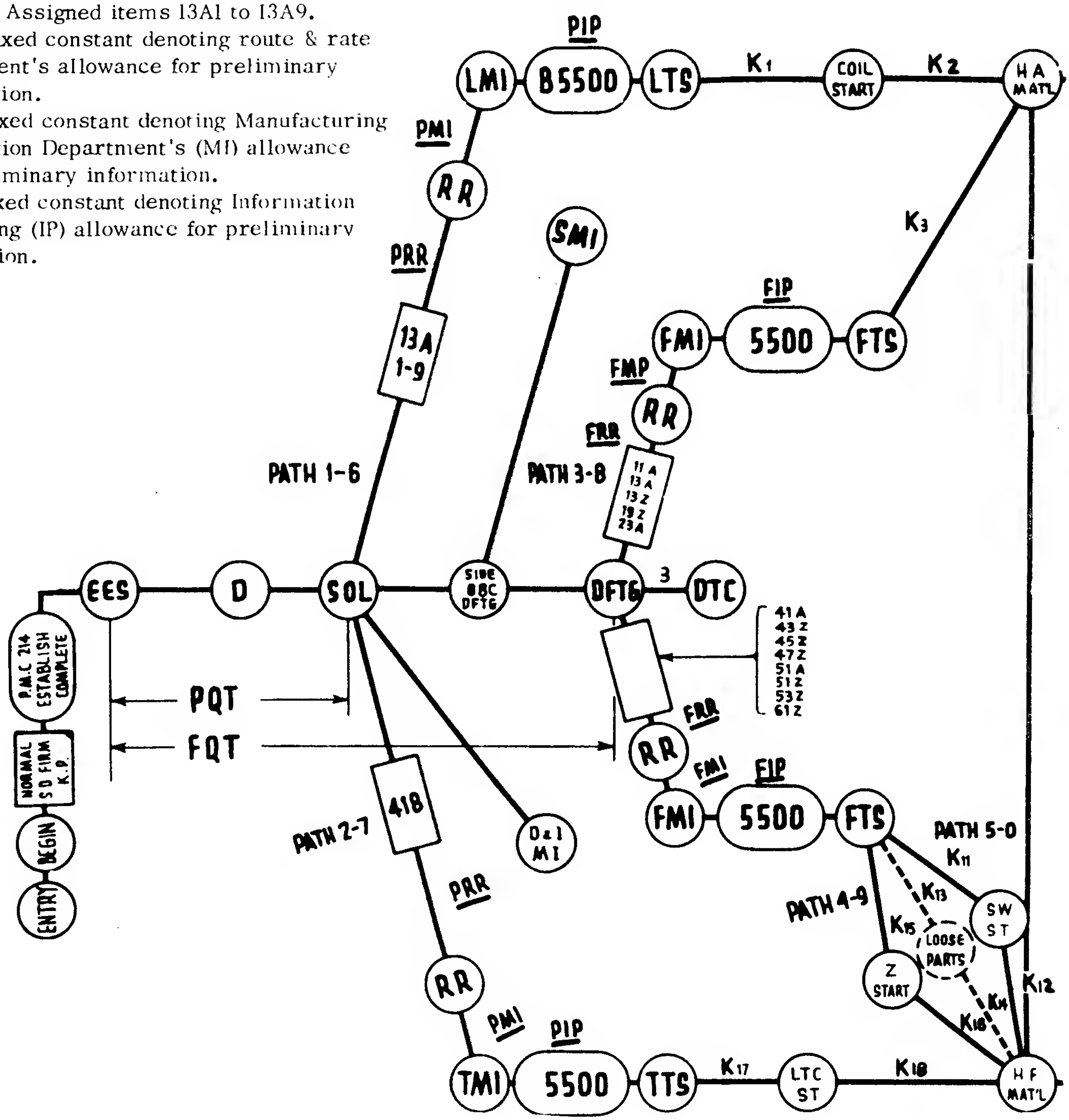
The number of manhours required in a certain activity (manufacturing process) may be quite small, though the elapsed time in the critical path may be quite long. For example, the number of manhours required to wind a coil may be quite small, but the activity would have to include the time in the queue of coils waiting to be wound. In situations where a project had become delayed (say, due to failure on test) and the total time required for the remaining critical path exceeded the promised delivery date, the analyst reduced all activities proportionately to eliminate the discrepancy in dates. In essence this meant giving queue priority to late jobs.

This reduction of all activities was acknowledged to be a crude approximation because some activities included proportionately more queue time than others. It was hoped some day to analyze the sequencing problem facing each coil winding machine so as to reduce the average time a coil would spend in queue. Mathematically it was easy to show that the average time in the queue could be reduced to a minimum if jobs were sequenced in order of their winding time, and the short jobs run first. However, the workers were on an incentive system which did not pay them for job set-ups. To them long jobs were gravy jobs. They therefore delayed short jobs for as long a period as possible.

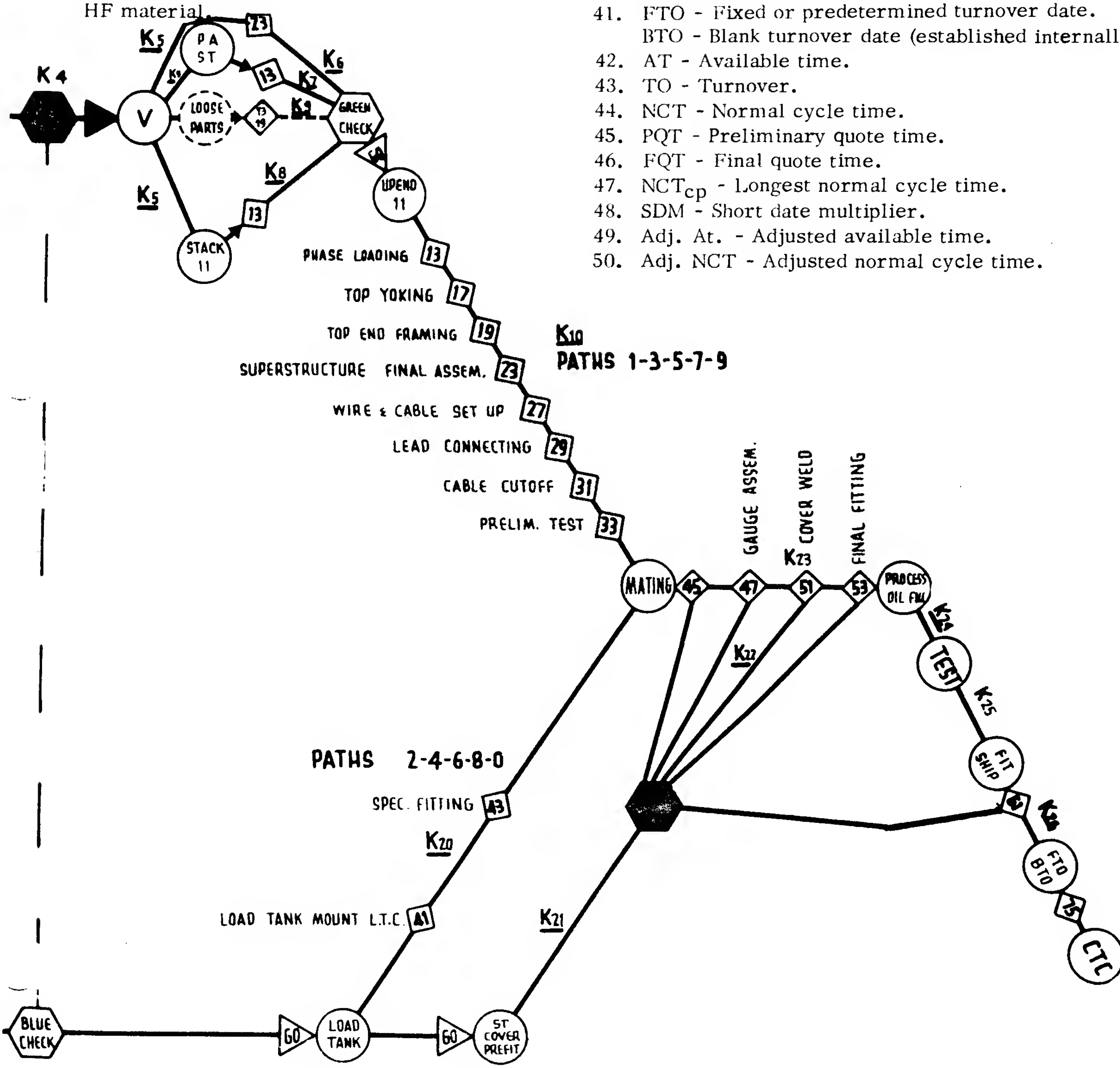
Note that squeezing queues was done only when the delay originated within the plant. The analyst in the transformer division recognized that if the first-in, first-out queue discipline were to be discarded then field sales engineers such as Nick Borris would want to affix individual due dates to individual orders. Some orders for a particular transformer would face stringent due date competition from other manufacturers and would therefore have to be expedited, whereas others would not. To avoid the confusion of individual priorities no analysis was done. Nevertheless, both production people and marketing people in the transformer division wondered about schemes by which priorities could be given to certain orders, and the benefits and costs of each scheme. For each scheme you suggest, discuss how the setting of due dates would be administered giving particular attention to "bumping", re-setting due dates of lower priority orders to make space for a high priority order; from this discussion outline how you would measure the benefits of each of your schemes. Set out computational techniques to be used by manufacturing for each scheme.

Figure 4: CRITICAL PATH DIAGRAM

1. Entry - Entry of customer order into production department.
   Begin - Earliest possible date for any event.
. Normal S.D. Firm - Description of type of order for which network fits; normal (zero slack), short date (neg. slack), firm (not approval).
4. EES - Earliest Engineering start.
5. D - D-spec due.
6. SOL - Shop order & L-spec due.
7. Side 88C dftg. - Series, Preventice auto or auxiliary transformer drafting due.
8. Dftg. - Main order complete drafting due.
9. DTC - Drawing to customer due.
10. 13A1-9 - Assigned items 13A1 to 13A9.
11. PRR - Fixed constant denoting route & rate department's allowance for preliminary information.
12. PMI - Fixed constant denoting Manufacturing Information Department's (MI) allowance for preliminary information.
13. pip - Fixed constant denoting Information Processing (IP) allowance for preliminary information.
14. K_n - Length of activity.
15. RR - Route & rate due.
16. LMI - L-spec MI due.
17. LTS - L-spec due to shop.
18. Coil Start - Coil winding start date.
19. HA Mat'l - Material due for core & core line assembly operations.
20. TMI - Tap changer MI.
21. TTS - Tap changer to shop.
22. LTC St. - Load tap changer start.
23. SMI - Side order MI.
24. FMI - Final MI.
25. FTS - Final to shop.



26. FRR - Fixed constant denoting R&R department's allowance for final information.
. FMI - Fixed constant denoting MI Department's allowance for final information.
28. FTS - Fixed constant denoting IP Department's allowance for final information.
29. SW St. - Switch start date.
30. Z Start - Z building (tank) start date.
31. HF Mat'l - Material due for tank assembly line operations.
32. Blue check - Material status check for HF material.
33. Go - Decision point.
34. Load tank - Tank loading date.
35. SS Start - Superstructure start date.
36. PA Start - Phase assembly start date.
37. Stack - Core stack start date.
38. Green check - Assembled component status check.
39. Upend - Latest date core due to be upended on drag chain.
40. Mating - Date core and coils and tank due to be joined.
41. FTO - Fixed or predetermined turnover date.
BTO - Blank turnover date (established internally)
42. AT - Available time.
43. TO - Turnover.
44. NCT - Normal cycle time.
45. PQT - Preliminary quote time.
46. FQT - Final quote time.
47. NCT_{cp} - Longest normal cycle time.
48. SDM - Short date multiplier.
49. Adj. At. - Adjusted available time.
50. Adj. NCT - Adjusted normal cycle time.



PART 7

Circuit Stability Studies (32 months before start up)

Ed Borrach's November 1964 presentation to Silicon Stainless engineers about load-tap-changing retrieved the New Orleans order for Ascendent. To Silicon Stainless, New Orleans was a prototype for their Detroit plant. So when the New Orleans furnaces failed repeatedly, confidence in the Detroit design was impaired. Each electric arc furnace was connected by thick copper bus bars to a furnace transformer behind a fire wall. Higher voltage, smaller cables led to the load-tap-changing transformer situated outside the building which was connected to a power transformer feeding from a 138 KV bus bar. Between the furnace transformer and the regulating transformer was a circuit breaker, and between the circuit breaker and the regulating transformer a bank of capacitors was installed to bring the current in phase with the voltage so that the power factor (the ratio of in-phase voltage to total voltage) would be almost 1 even during the scrap melt down time. Ed Borrach anticipated that whenever a circuit breaker was closed, the bank of capacitors would cause the circuit to resonate at the fifth harmonic of the 60 cycle per second line frequency.

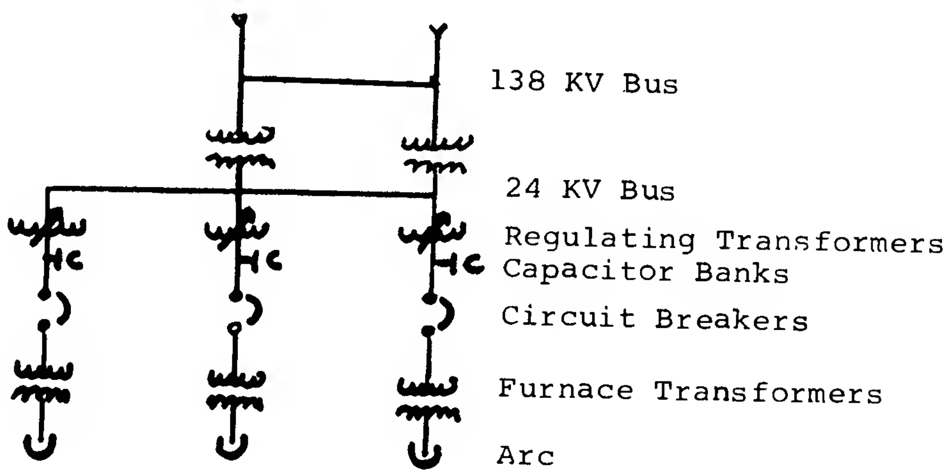


Figure 5: CIRCUIT DIAGRAM OF THREE ARC FURNACES

The first transformer failure at New Orleans occurred in September 1966, one week after start-up. There had been winding failure in the load-tap-changing regulating auto transformer. The load tap changing transformer was removed from service, and the furnace operated (at reduced capacity) by feeding the furnace transformer directly from the power transformer. Repairs would require five months work. The failure was corrected by rewinding the coils to distribute the voltage more evenly through the winding configuration. The second transformer blew in

October 1966, so it too had to be removed from service and its coils rewound in the revised configuration. It was discovered that the transformer lightning arresters had blown, indicating that they had been subject to power surges of many micro seconds.

The first transformer was put back into service in February 1967 and failed again within a week. It was believed that there was contamination from the first failure, that copper spots had been left in the winding. When the second transformer was put back into service it operated until June 1967 when a flash over in the load-tap-changing transformer permitted a short circuit current which distorted the windings.

The fifth failure occurred in January 1968. The power company had two separate power lines to supply the New Orleans plant. On humid days there would frequently be corona arc-overs so that one line or the other would go out for a few milliseconds In January 1968 arcing occurred simultaneously on both lines connected to the Silicon Stainless New Orleans plant. Within a few milliseconds the circuit breaker of the power company reclosed so as to resume service to the arc furnaces. It reclosed at precisely the wrong moment, for resonance from the power being shut off was added to by the resonance of the power being turned on again and the transformer blew. This fifth failure was corrected by having the power company delay one second before resuming service. But problems that caused the first four failures were less easy to remedy.

The Pittsburgh Headquarters of Silicon Stainless designated one of their senior engineers to be the focal point for all communications about the problems of instability in electric arc furnaces. He created a task force consisting of himself, the electrical engineer from St. Louis, the electrical engineer from New Orleans, and the electrical engineer from Detroit. All members of the committee attended every meeting with an outside agent (such as Nick Borris of Ascendent). Furthermore, they made a point of being in frequent phone contact, preferably with conference calls. They hypothesized that if the two furnace New Orleans circuit had regions of instability due to resonance, then the three furnace Detroit circuit would have larger regions of instability.

The irony of this repeated circuit failure lay in the fact that Ascendent Electric had a reputation for over-designing their equipment, especially equipment destined for steel mills. Back in the days when steel companies employed few electrical engineers, Ascendent built a reputation of providing designs that were robust, reliabile, and required little maintenance. Customers expected over-design, for it saved them the need to write specifications about every minute detail. In designing each transformer for both New Orleans and Detroit, Ed Borrach had included special insulation, double tube cooler, a sudden pressure relay, a hot spot indicator, and extra class insulation on the bushings. Furthermore, since he was exploring a new area of design, he had made his design especially conservative.

Nick Borris and all Ascendent salesmen dealing with the steel industry, faced the prospect of selling a product which had failed in service, for reasons that were not yet understood. Word of the failure spread through the steel industry, and through late 1966 and early 1967 Ascendent lost order after order to other manufacturers of electrical equipment for arc furnaces. By mid-1967 opinion swung to the other extreme, and Ascendent acquired the reputation of being the only company with field experience at stabilizing resonance surges in arc furnace control transformers. Nick Borris, and the district engineer who worked with him, Fred Shore, had both become avid students of resonance instability.

After the first failure in September 1966 Ascendent had attached to the circuit a great deal of monitoring equipment. The purpose was to capture an oscillograph photograph of a resonant surge. Surges occurred whenever a circuit breaker for the furnace was opened or closed and so a portfolio of pictures was taken. Voltage surges of twice the peak voltage were common; they lasted less than a millisecond and were photographed as a narrow spike. Occasionally, however, the spike would be followed a few milliseconds later by a second spike which, though not as intense, lasted appreciably longer. Failures were attributable to this long second spike. In electric power engineering there is a rule of thumb that one should not tap a regulating transformer below 90% on input voltage and should not vary the tapped voltage by more than $\pm$10% to avoid resonance problems. This rule limits the voltage range to 100%-80%. For an arc furnace the range of voltage required was 100%-40%.

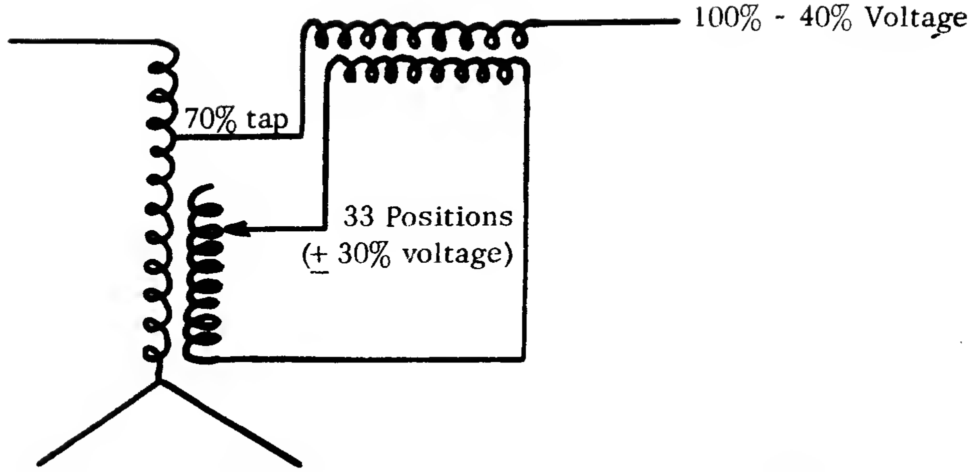


Figure 6: WINDINGS OF THE REGULATING TRANSFORMER

A simulation performed at Ed Borrach's suggestion by the Electric Utility Headquarters Department of Ascendent showed that when the three sets of windings resonated out of phase the output voltage occasionally had peaks of up to 540% of the mean voltage. The problem of natural frequency resonance was compounded by the large capacitor banks with their own resonant behavior. The Electric Utility Headquarters Department simulated the circuit on an analog computer to search for combination of the three voltage regulating tap positions resulted in unstable voltage surges when a circuit breaker was closed. When these surge areas had been determined approximately, a digital computer study was performed to delineate the resonant areas more clearly. In part, the report of the Electric Utility Headquarters Department said, "A single branch circuit can be resonant to fifth, sixth, and seventh harmonics. Fifth harmonic resonance would occur at the highest taps, sixth at the intermediate, and seventh at the lowest. In general, as tap position is lowered, the circuit becomes resonant to a higher harmonic." As a result of this study, Ascendent wanted to change the Detroit design. Ed Borrach wanted to add reactors in the capacitor circuit and to add additional lightning arresters on the switching circuit. If the various tap positions of the three load tap changing transformers are thought of as coordinates in three dimensional space, then contours of instability may be depicted as three dimensional bodies. The circuit would be adequately stable if certain combinations of tap positions would be avoided, and this would be done by programming the process control computer appropriately. The simulation to find these unstable areas had cost well over $20,000. Who was to pay?

When Nick Borris sold the arc furnace equipment he had tried also to sell a system warranty. Silicon Stainless had refused to buy. Ascendent warranted the various products as meeting the specifications set by Frazer Engineers and Silicon Stainless Steel. But no warranty had been sold stating that the pieces of equipment would interact to attain a specified purpose. A systems warranty would have stated that:

> The sub-system quoted herein will perform in the manner stated in this proposal, provided the actual operating requirements for each item of equipment are as outlined in such proposal and are within the rating of such items as specified in such proposal and provided the purchaser has fulfilled all of the obligations imposed on it by the following:
>
> A. The purchaser shall provide the application and apparatus studies and shall warrant the amount of power required to be transferred to the arc furnace. Ascendent shall provide studies of the sub-system (the equipment between the point of power supply from the external source and the arc furnace secondary terminals) to determine whether the equipment specified by the purchaser will operate within the conditions specified without ferro-resonant conditions or other transient instabilities. Should these studies show any such condition or instability, the purchaser shall either change the ratings of the equipment ordered or order additional equipment so as to resolve such problems.
>
> B. In the event that the purchaser shall have complied with all the foregoing, Ascendent shall, by repair replacement or by supplying additional equipment F.O.B. its plant, and provided prompt notice of any defect shall have been furnished to it by the purchaser, correct any failure to perform in accordance with the specifications which shall appear within one (1) year after the date of shipment, or the contract warranty period except for such failures as may result from the interrelation between the power supply and the arc furnace (such as, for example, utility voltage flicker, synchronous condenser and buffer reactor application, or harmonic frequency current flow in the utility system).

Despite the absence of a system warranty, a great deal of design engineering was being performed to assure that the system would function properly. There was an informal sense of responsibility, a commitment to get the project to function.

The Manager of Industrial Project Marketing in Ascendent was well aware of the eagerness of Nick Borris to provide information to Silicon Stainless. After all, the study had been performed, the $20,000 had been spent, the computer program for the process control computer had been programmed by Ascendent to avoid unstable combinations of tap positions. In this case, there was little to be gained by not revealing these tap combinations to Silicon Stainless. On the other hand, giving the information freely was establishing a very bad precedent. Ascendent was probably not the lowest cost producer of transformers and its marketing advantage lay in its implicit consulting engineering. It would be an empty gesture to try to sell a systems warranty if those who did not buy such a warranty received the same service as those who did. If sales performed a superb analysis of sequencing the customer's expansion but did not charge for it, what would prevent the customer from awarding his order to the lowest bidder (whose overhead costs were low for it provided no engineering support)? Just what was Ascendent marketing?

What policies should Ascendent develop to control engineering studies performed to benefit a customer, and how could the policy be implemented without impairing the morale of salesmen and the cooperativeness of the design engineers?

EPILOGUE

The melt shop was scheduled for completion in September 1968, but construction delays occurred. Frazer Engineers worked their men overtime in an attempt to start up one furnace by December 31, 1968 (to obtain a depreciation allowance for that year). This effort was thwarted when employes of the manufacturer of overhead cranes, required in the melt shop, went on strike. The construction crews then slackened, and the first furnace was not started up until March 1969.